High Resolution Climate Data From Research and Volunteer Observing Ships

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PROJECT SUMMARY

This project involves the measurement of direct high-resolution air-sea fluxes on one to two cruises per year and the development of a roving standard flux measuring system to be deployed on a series of NOAA and UNOLS research vessels to promote the improvement of climate-quality data from those platforms. An adjunct task is maintenance and operation of the C-band scanning Doppler radar and the stabilized wind profiling radar on the NOAA ship *Ronald H. Brown*. Because buoys and most ships and satellites rely on bulk methods to estimate fluxes, another aspect of this project is the use of direct measurements to improve the NOAA/COARE bulk flux algorithm. Originally one cruise was the annual TAO buoy tending cruise to 95 and 110 W on the *Ronald Brown*, but that has been discontinued in favor of an annual cruise to the equatorial Atlantic Ocean with Dr. Bob Molinari (AOML) as part of the African Multidisciplinary Monsoon Analyses (AMMA) and Saharan Dust studies. The second cruise, which also occurs in the fall, is the annual excursion to turn around the Stratus climate buoy at 20 S 85 W. A full suite of direct, inertial-dissipation, and bulk turbulent fluxes are measured along with IR and solar radiative fluxes, precipitation, and associated bulk meteorological properties. This effort represents a partial transition of research from the OGP CLIVAR PACS program to operations under the Climate Observations Program (COP).

The project development is the result of a recent NOAA-sponsored workshop on high-resolution marine measurements (Smith et al., 2003, *Report and Recommendations from the Workshop on High-Resolution Marine Meteorology*, COAPS Report 03-01, Florida State University, pp38) which identified three important issues with the planned NOAA air-sea observation system: 1) the need for a data quality assurance program to firmly establish that the observations meet the accuracy requirements, 2) the need for observations at high time resolution (about 1 minute), 3) and the need to more efficiently utilize research vessels, including realizing their potential for the highest quality data and their potential to provide more direct and comprehensive observations. For seasonal time scales, the net air-sea flux (sum of 5 flux components) must be constrained within 10 Wm^{-2}. Buoys and VOS systems are required to operate virtually unattended for months, so considerations of practical issues (e.g., power availability, instrument ruggedness, or safe access) are balanced against inherent sensor accuracy and optimal sensor placement. As discussed above, an important function of the in situ measurements is to provide validation data to improve NWP and satellite flux fields. Here, high time resolution and more direct observations are invaluable for interpreting surface flux measurements and diagnosing the source of disagreements; such information can be provided by suitably equipped research vessels (R/V). Thus, the accuracy of buoy and VOS observations must be improved and supplemented with high-quality, high time resolution measurements from the US R/V fleet (which is presently underutilized). The necessity for both high time resolution and high accuracy places extreme demands on measurements because some sources of error (such as the effect of ship flow distortion on wind speed) tend to average out over a large sample.

To accomplish this task will require a careful intercomparison program to provide traceability of buoy, VOS, and RV accuracy to a set of standards.

This project directly addresses the need for accurate measures of air-sea exchange (Sections 5.2 to 5.4, *Program Plan for Building a Sustained Ocean Observing System for Climate*. The project is a joint effort by ESRL and Dr. Robert Weller of the Woods Hole Oceanographic Institution (WHOI). NOAA COP funds the ESRL component and Dr. Weller is seeking NSF fund for the WHOI component. The ESRL Air-Sea Interaction Group website can be found at: http://www.etl.noaa.gov/et6/air-sea/. ESRL also cooperates with Dr. Andy Jessup (APL University of Washington) on radiative sea surface temperature measurements, Dr. Frank Bradley (CSIRO, Canberra Australia) on precipitation, Drs. M. Cronin and N. Bond (PMEL) on buoy-ship intercomparisons and climate variability analysis, and Dr. Mike Reynolds (DOE BNL) on radiative fluxes. A new website is under construction for this project (High Resolution Climate Observations http://www.esrl.noaa.gov/psd/psd3/air-sea/oceanobs/). An associated website (http://www.esrl.noaa.gov/psd/psd3/wgsf/) contains a handbook on best practices for flux measurements plus a database of high-resolution flux data. This work will be closely monitored by the new WCRP Working Group on Surface Fluxes (WGSF) which is chaired by C. Fairall. This will give the project high visibility in the CLIVAR, GEWEX, and SOLAS programs. This project will be managed in cooperation with JCOMM (and other) panels as per instructions of Mike Johnson.

FY2006 ACCOMPLISHMENTS

For the *Ronald Brown* C-band and wind profiler radar project, routine maintenance was performed on the wind profiler at Charleston, SC, prior to the NOAA 2006 AMMA in June and July 2006.

ESRL completed two research cruises as planned: the Bob Molinari buoy deployment cruise in the Atlantic in the summer of 2006 (this is the *AMMA/Saharan Dust* cruise) on board the R/V *Ronald H. Brown* and the joint ESRL/WHOI cruise to the climate reference buoy (25 S 80 W), also on board the *Brown* in October 2006. The preliminary processed data can be found at ftp://ftp.etl.noaa.gov/et6/archive/

A synthesis of the main results of the previous five years of strategic observations were produced in the form of three scientific publications (two have appeared in print and one is submitted). The first two (Cronin et al., 2006a and 2006b) dealt with the quality of TAO buoy observations (through intercomparison with ESRL ship data) and analysis of the annual cycle of turbulent and radiative fluxes. Deficiencies in satellite and operational numerical weather prediction (NWP) surface fluxes in the Eastern Equatorial Pacific were identified. The third paper (Fairall et al., 2006) dealt with the analysis of radiative cloud forcing based on the four years of ESRL ship-based observations. Here the emphasis was on the linkage cloud forcing to cloud properties such as fractional coverage and liquid water path. This paper showed that the three observational data sets (ESRL ship data, TAO buoy data, and ISCCP satellite estimates) agreed much more closely than NWP estimates, which have considerable problems with the representation of clouds.

Considerable progress was also made on developing the portable flux standard and implementing ship and buoy intercomparisons for quality assurance. Dr. Frank Bradley of CSIRO Canberra Australia visited ESRL for a month in the spring of 2006 to work on the flux

measurement handbook. Considerable progress was made and a draft was circulated among coauthors. The handbook has now been published as a NOAA Technical Memorandum (ftp://ftp.etl.noaa.gov/user/cfairall/wcrp_wgsf/flux_handbook/). Production of the roving flux standard is nearly complete. We have upgraded one of the existing ESRL flux systems to create the portable standard (i.e., rather than build an entire new system from scratch). The upgrade features two parts: 1) convert from a network cabled sensors to wireless transmission and 2) improve the radiative flux and navigational measurements. The first step is to simplify the shipping, installation, and tear down process so that it is cheaper and more practical to operate on a series of ships. The second step is necessary to close some accuracy shortcomings, balance the sources of error between radiative and turbulent fluxes, and take advantage of recent developments in GPS technology.

*Wireless hardware was acquired in FY2005. A field test was conducted in Boulder in June and a prototype system was installed on the *Brown* at WHOI. The fall Stratus 2005cruise was done with the prototype system. Some technical problems were encountered (including loss of data) and we are working on fixing that.

*A market survey of pitch/roll compensation systems for the radiative flux measurements was conducted and a suitable system could not be located for a reasonable cost. A system was designed in-house at ESRL and components were ordered in FY2005. The system was built in 2006 and laboratory motion tests were conducted. The system will be field tested in FY2007.

The PI of this project has been chair the WCRP Working Group on Surface Fluxes (WGSF) since 2003. He also serves on the International Geophysical Union International Climate Dynamics and Meteorology Working Group A (Boundary Layers and Air-Sea Interaction). In 2004 he was invited to join the SOLAS Focus 2 (air-sea flux physics) Working Group to develop the Surface Ocean-Lower Atmosphere Study (SOLAS) International Implementation Plan and has been named to the US SOLAS Advisory Group.

PUBLICATIONS (FY 2006)

Wick, Gary A., J. Carter Ohlmann, Christopher W. Fairall, and Andrew T. Jessup, 2005: Improved oceanic cool-skin corrections using a refined solar penetration model. *J. Phys. Oceanogr.*, **35**, 1986-1996.

Zhou, Mingyyu, Xubin Zeng, Michael Brunke, Zhanhai Zhang, and C. W. Fairall, 2005: Study on macro- and microphysical properties of stratus and stratocumulus over the Eastern Pacific. *Geophys. Res. Lettl.*, **33(2)**, Art. No. L02807.

Cronin, M. F., N. Bond, C. W. Fairall, and R. A. Weller, 2006: Surface cloud forcing in the Eastern Tropical Pacific. *J. Clim.*, **19**, 392-409.

Cronin, M., C. W. Fairall, and M. J. McPhaden, 2006: An assessment of buoy-derived and NWP surface heat fluxes in the Tropical Pacific. *J. Geophys. Res.*, **111**, C06038, doi:10.1029/2005JC003324.

Grachev, A. A., E. L Andreas, C. W. Fairall, P. S. Guest, and P. O. G. Persson, 2006: SHEBA flux-profile relationships in the stable atmospheric surface layer, *Boundary-layer*

Meteorol., accepted.

Fairall, C. W., J. E. Hare, Ludovic Bariteau, A. Grachev, and R. J. Hill, 2006: Coastal effects on turbulent bulk transfer coefficients and ozone deposition velocity in ICARTT. *J. Geophys. Res.*, accepted.

Fairall, C. W., J. E. Hare, T. Uttal, D. Hazen, Meghan Cronin, Nicholas A. Bond, and Dana Veron, 2005: A seven-cruise sample of clouds, radiation, and surface forcing in the Equatorial Eastern Pacific. *J. Clim.*, submitted.

CONFERENCES (FY 2006)

27h Session of the Joint Scientific Committee for the WCP, World Climate Research Program, Pune, India, 3-22 March, 2006 Presentation: The WCRP Working Group on Surface Fluxes.

First Joint SAMOS/GOSUD Workshop, Boulder, CO, 2-4 May, 2006. Paper presented: High-Resolution Climate Data from Research and Volunteer Observing Ships: A Strategic Intercalibration and Quality Assurance Program.

Office of Climate Observation 3rd Annual System Review, NOAA, Silver Spring MD, 10-12 May 2006. Poster presented: The NOAA Portable Seagoing Air-Sea Flux Standard.

Focus 2 Working Group for the International SOLAS Implementation Plan, Surface Ocean-Lower Atmosphere Study, IGBP, Heidelberg, Germany, 4-8 September, 2006. Paper presented: Updates on the WCRP WGSF.